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NEWSLETTER

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Fixing Those Ill-Fitting Rocket Parts

Cover Photo: The Rising Star rocket kit takes off on another great flight. Get it at: www.ApogeeRockets.com/Rocket_Kits/Skill_Level_2_Kits/Rising_Star_Rocket_Kit

Apogee Components, Inc. — Your Source For Rocket Supplies That Will Take You To The “Peak-of-Flight”
3355 Fillmore Ridge Heights
Colorado Springs, Colorado 80907-9024 USA
www.ApogeeRockets.com e-mail: orders@apogeerockets.com
Phone: 719-535-9335 Fax: 719-534-9050

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Fixing Those Ill-Fitting Rocket Parts

By Tim Van Milligan

The Perfect Fit

Did you ever get a kit, and find out some of the parts, like the centering rings, don't fit quite right? Maybe the rings were too loose or too tight, or the nose cone didn't fit the tube properly. What are you going to do?

Everyone likes to work with parts that go together easily and quickly. It makes assembly fast and enjoyable. It also makes the lightest weight rockets. Any time you are adding shims to a loose part, you end up adding a little bit of extra weight.

You have two options. If it is a kit that you paid money for, you'll probably return it to the manufacturer. If it is a part that you made yourself, the dilemma is a little bigger because there is no one to blame. You can start over and make a new part, or you can modify the part to make it fit.

The fact is, parts don't always fit perfectly. It makes sense to be able to fix parts to achieve that perfect fit.

In this article, we'll discuss the different ways you can modify parts to get them to fit properly.

Centering rings and nose cones are the two types of parts that are the most prone to being mismatched.

The best way to describe the fit of a nose cone is that if you turn the rocket upside down, the nose cone should stay in the tube. But if you wiggle the rocket while in this position, the nose cone should start to work its way out.

If the nose cone is too loose, the solution to tighten it up is easy. Just wrap masking tape around the perimeter of the shoulder. I like to put the tape near the top of the shoulder, so it is closest to the end of the tube. The reason for this is that once the taped section exits the tube, the nose essentially is free of the tube, since the bottom portion of the shoulder has a loose fit. I don't have to worry about the nose cone binding in the tube at all.

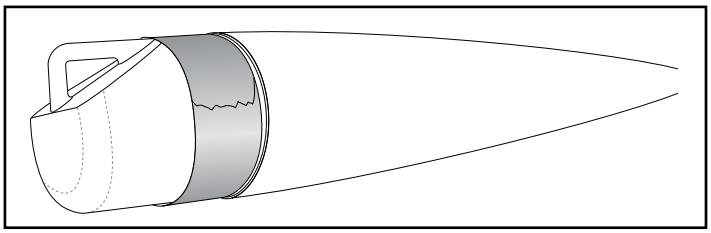

Figure 1: Fixing a loose fit on a nose cone can be done by wrapping tape around the shoulder.

A tight nose cone is much more of a difficult problem to fix. It might not even be solvable, depending how tight the fit is, and what material the nose and tube are made from. Balsa wood nose cones are the easiest to fix, because you can simply sand down the shoulder to make them fit into the tube.

Plastic or fiberglass nose cones are much more difficult to fix. If the fit is just a little bit too tight, then you can sand down the shoulder. But if it is way too tight, then you'll either have to find a new nose cone or a new tube to put it into.

Tube couplers are a lot like nose cones. If they are too loose, use masking tape to tighten the fit. If they are too tight, you can peel off some of the layers of paper to make them fit. But if you end up making the wall thickness of the tube too thin, you are better off finding a different tube coupler for the rocket. There is a video on the Apogee web site that shows how to make a tube coupler out of a body tube (www.ApogeeRockets.com/Advanced_Construction_videos/Rocketry_Video_8). It has gotten me out of many situations when I didn't have perfect fitting couplers.

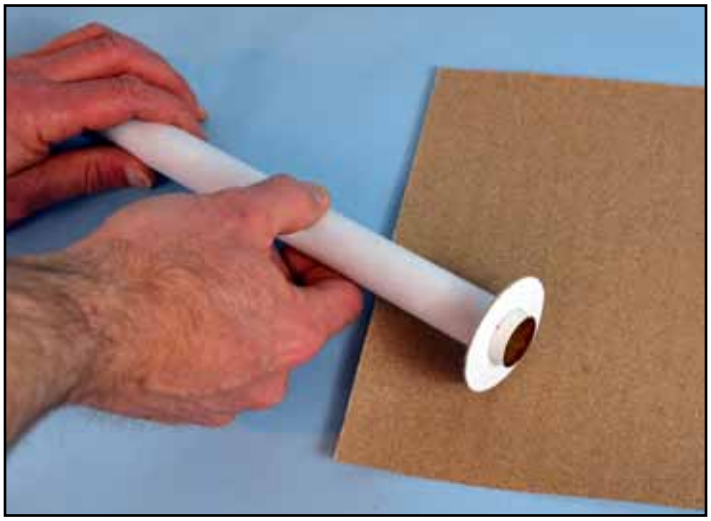

Figure 2: Keep rotating the ring when sanding the outside edge. Mounting it to a body tube helps a lot.

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Newsletter Staff

Writer: Tim Van Milligan
Layout / Cover Artist: Tim Van Milligan
Proofreader: Michelle Mason

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Centering rings are typically easier to fix than nose cones. If the fit is too tight when sliding it into the big tube, then sanding the outside of the ring will reduce the diameter. You just have to be careful not to sand a flat spot into the ring. The key is to spin the ring while you're sanding the outside perimeter.

I like to put the ring onto a tube so that I can use the tube as a handle and spin it on the sandpaper, as shown in Figure 2. I prefer to glue it to the tube, so that it doesn't slip when I rotate the tube. I've even used this technique when using a belt sander to resize the ring. But it takes a gentle hand, because a belt sander will take off a lot of material quicker than you expect. I usually end up with an out-of-round piece whenever I use a belt sander, which has to be fixed later with some Fix-It Epoxy-Clay to seal up the opening (www.ApogeeRockets.com/Building_Supplies/Epoxy_Clay/FIXIT_Epoxy_Clay).

Paper rings can be a challenge to sand. The paper edge will often fray and splay out as shown in Figure 3 because it is rather soft. To fix this issue, saturate the edge of the paper with some thin viscosity CA glue. When it cures, it will stiffen up the edge and make it easier to sand. I typically will sand the diameter to the right size, and then add the CA glue. Then I only have to sand the ring flat again, which is easier to do than trying to sand the outer diameter.

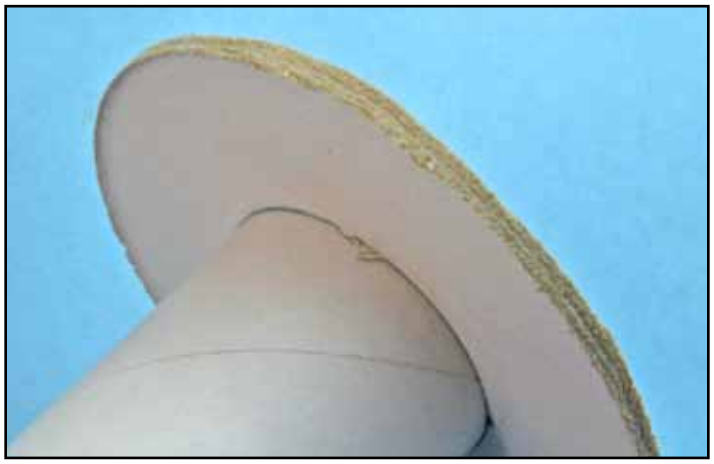

Figure 3: The edge of a paper ring can get fuzzy when sanding. Use thin CA glue to stiffen up the fibers.

Sanding the inner diameter of the ring that is too tight is also pretty easy. I prefer to wrap sandpaper around a wood dowel or a rocket engine and use that to sand down the edge. Again, spin the dowel so that you limit the chances of creating a flat spot in the hole.

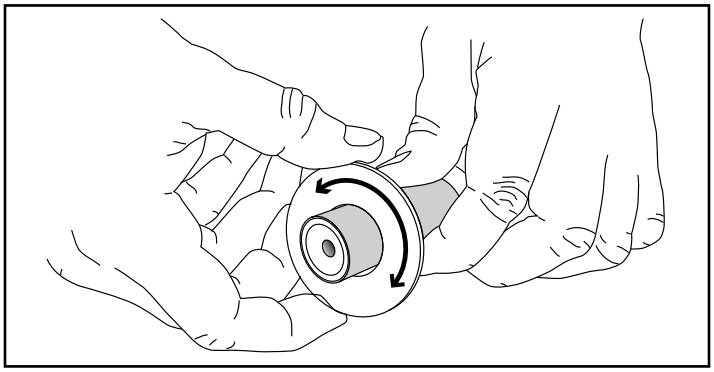

Figure 4: Wrap sandpaper around a dowel and use that to sand the inside edge of a ring.

Rings that are too loose require a shim to fill the gap. To fix the inside hole, you'll need to wrap masking tape around the perimeter of the tube that the ring fits over. Try to use thin tape, such as 1/8" wide as shown in Figure 5 on the next page. You can always cut strips of tape with a ruler and a sharp hobby knife.

Now the tape on the tube is very weak, as the ring could easily slide off the tape. To solve this problem, you'll need to put a fillet of glue over the joint between the tape and the ring. The fillet must extend past the tape, and down

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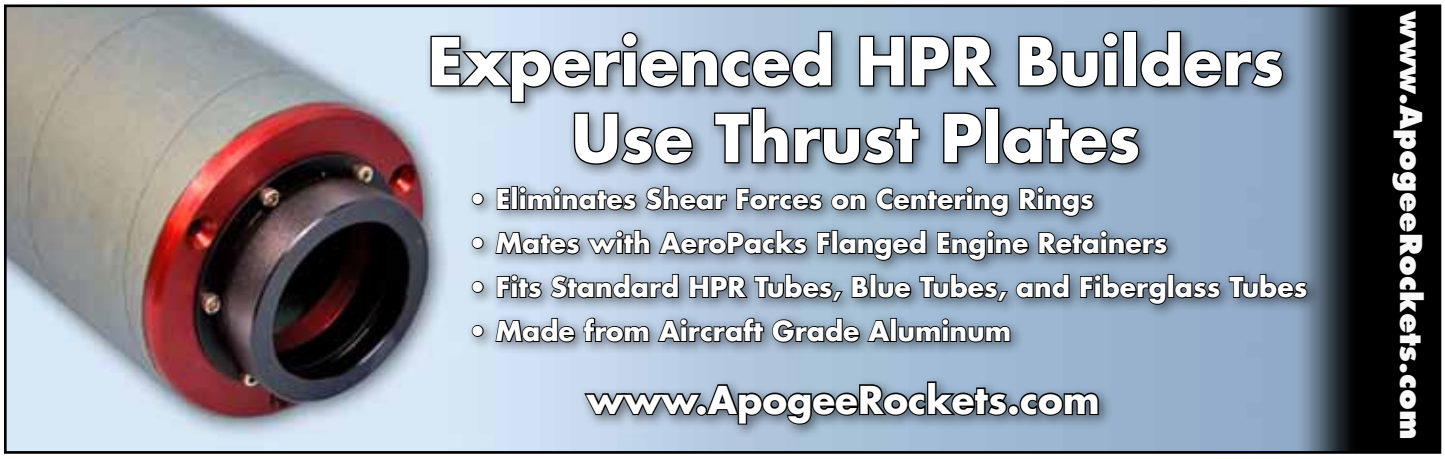

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Fixing Ill-Fitting Rocket Parts

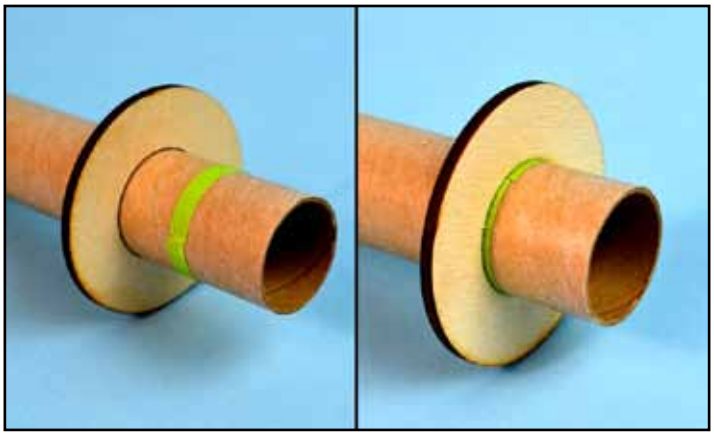

Figure 5: Wrap sandpaper around a dowel and use that to sand the inside edge of a ring.

to the tube itself. That way it has something firm to grip on to. And that is why I recommend thin tape, so that you don't have to add a lot of weight by extending the fillet a long way to get past the edge of the tape.

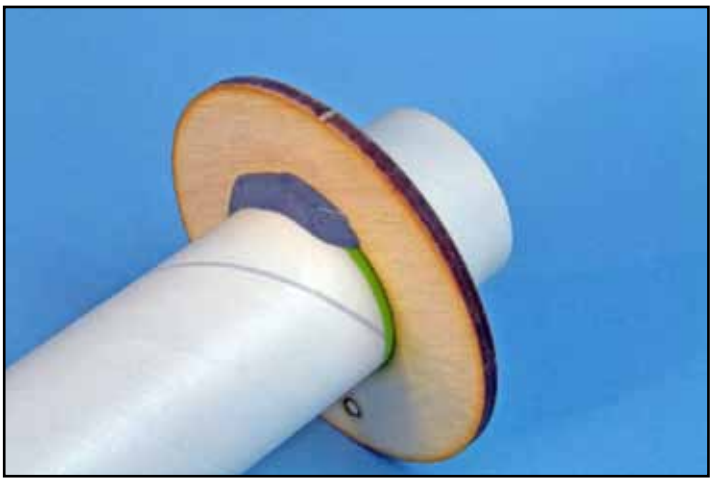

Figure 6: Make sure your fillets extend past the edge of the tape so the ring won't slide on the tube.

I prefer to use the Fix-It epoxy clay to make these fillets. You can shape the clay fillets easily to cover over the edges of the tape, without adding a lot of weight to the rocket.

Unfortunately, fixing a loose fit on the outer edge of the ring is not as easy. You can't use tape, because first of all, it is next to impossible to apply tape to the inside of a tube, especially if the ring has to go deep into the tube.

And second, you shouldn't use masking tape on the outer perimeter of the ring. Since the adhesive on the back of the tape is weak, the ring will undoubtably slide out of the tape as soon as you try sliding it into the tube. Been there, done that...

The solution in this situation is to glue strips of paper to the outer edge of the ring as shown in Figure 7. The key ingredient here is the glue, since it will grab tightly to the edge of the ring.

Cut long strips of paper slightly wider than the thick-

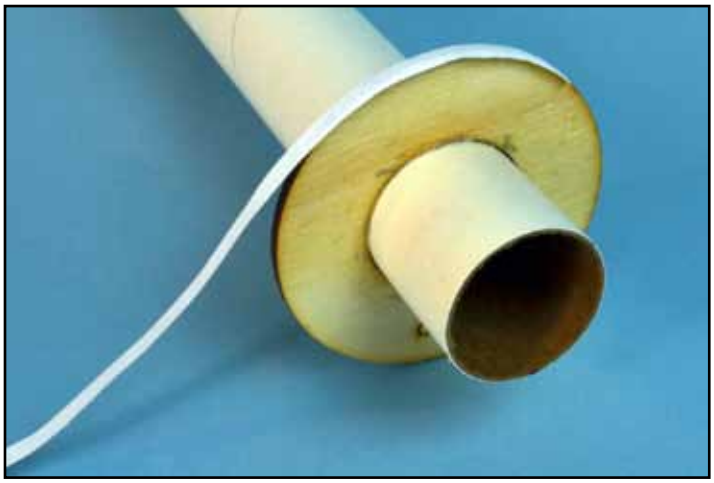

Figure 7: Glue strips of paper to the outer edge of a ring to make it a tighter fit into the tube.

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Fixing Ill-Fitting Rocket Parts

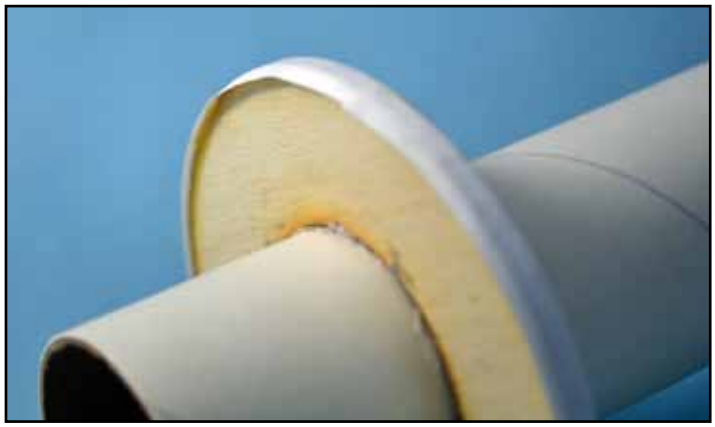

Figure 8: Cut or sand off the excess paper that hangs over the flat face of the ring.

ness of the ring. Lay the strip(s) down on piece of plastic, and smear glue over them. Then carefully pick them up and wrap them around the perimeter of the ring. Again, I like having the inner tube glued into the ring at this point, so that you can use it as a handle to spin the ring. Spinning the ring makes it a lot easier to align the thin strip of paper to the outer edge of the ring.

You'll probably end up making the diameter too big by adding too much paper. Not too worry, as the excess can be sanded off later after the glue has dried. Even if the outer diameter is correct, wait until the glue has dried before you insert it into the tube.

Once the glue has dried, you can sand off any paper that hangs over the edge of the flat face of the rings as seen in Figure 8. This just makes it a little easier to slide the modified ring into the tube of the rocket.

With the exception of fiberglass rings, this method of gluing a paper strip to the perimeter is going to give you a part as strong as the ring itself. And when you put the ring into the tube, again add a fillet of glue over the joint to provide extra strength.

This time, a liquid epoxy (like the Double Bubble epoxy - www.ApogeeRockets.com/Building_Supplies/Adhesives/Double_Bubble_Extra_Fast_Epoxy_Packet) works better than the Fix-It epoxy clay. The reason is that you can smear a bead of liquid epoxy deep into the tube with a wood dowel, and just slide the ring through it. The ring will squeegee enough epoxy from the inside surface of the tube to create a uniform fillet around the ring. Obviously, keep the rocket pointing upright after you slide in the centering rings when using liquid epoxy, as it will run on you if you flip it over.

For the back-side fillet on the bottom ring of the rocket, I again use the Fix-It epoxy. You can smooth it out with your finger to make it nice and pretty, and you don't have to worry about it running on you.

The final place where I see ill-fitting parts is in slots cut in body tubes for through-the-wall fin tabs. Typically they are cut too wide and long, leaving a gap around the pe-

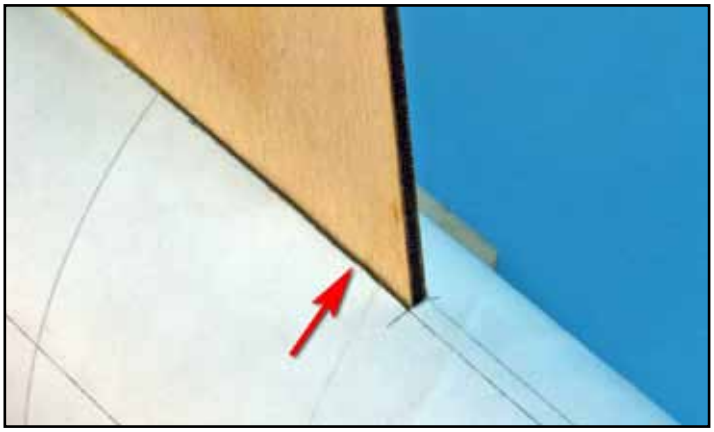

Figure 9: The gap along a fin slot can be covered with an epoxy fillet.

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rimeter of the fin. This is an easy fix, and for this I just add epoxy fillets to cover the gap. Not only does it fill the gap, but it adds even more strength to the fin joint.

Designing Tight Fitting Parts

If you're designing your own parts for your rocket, you have the opportunity to design a tight fit before you make the parts.

The tool that helps me the most is a digital caliper, which is seen in Figure 10. It allows you to measure parts with high accuracy. And that is what you need to keep your tolerances tight. Before you start cutting any parts like centering rings, you'll want to measure everything (such as the tubes that they mate to), just to confirm than they were constructed to specifications.

When two parts fit together, you want to allow just a slight amount of room for them to slide over each other, and for a thin film of glue to bond them together. Creating a centering ring is a good example.

The inside diameter of the tube can't be the same dimension as the outer diameter of the ring. For example, a BT-80 tube has an inside diameter of 2.558 inches. The ring can't have the same diameter, or it will be a very tight fit to get it into the tube. My rule of thumb is to make the ring .006 inches (0.15mm) smaller than the inside diameter of the tube. That same dimension goes for tube couplers and shoulders on nose cones.

Figure 10: A digital caliper allows you to take precise measurements of the parts you want to mate together.

For reference, a sheet of photocopy paper has a thickness of 0.004 inches (0.10mm), so the gap we're leaving is just slightly thicker than a sheet of paper. And since it is a diameter, that gap has to be split up so there is a little room all the way around the perimeter of the ring. In other words, the gap between the outer edge of the ring and the inside edge of the tube is .003 inches. That means you couldn't even slip a piece of paper in the gap around the entire ring.

When you cut the ring, you also have to take into account the width of the cutting blade. This is called the kerf. Don't cut exactly on the line, you want the edge of the cutting blade to be on the outside of the line so you don't take away too much material. Otherwise you'll have a loose fitting part.

Laser cutters are becoming more prevalent in rocketry, so if you have access to one, you'll want to design for the width of the cutting beam too.

It took me a while to learn this too. The first rings that I cut using the laser were all too loose and the parts fit sloppy. I forgot to allow for the kerf of the laser. The laser cutter that is used to cut our centering rings has a beam width of 0.005 inches.

For example, if I was cutting a ring to fit into a BT-80 size tube, I want the outside edge of the ring to be 2.552 inches. Remember, it has to have a slight gap, so it has to be 0.006 inches smaller than the 2.558 inch diameter of the

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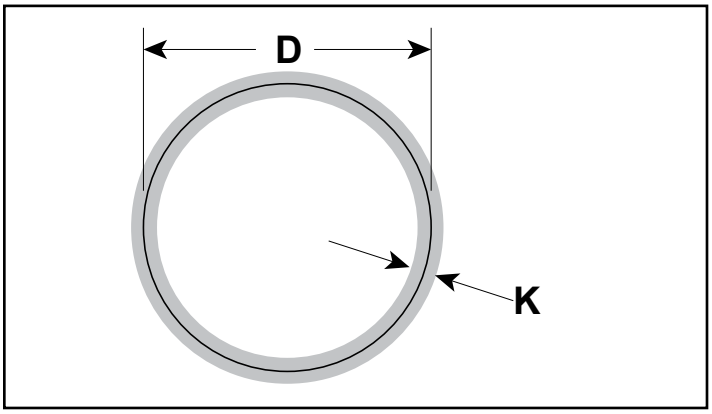

Figure 11: Dimension D is the nominal diameter of the circle. It is what we desire the circle to be. But the laser beam that cuts the circle has a width (dimension K). This is called the kerf width. It will remove the shaded area, and make the circle undersize.

tube.

But if I set the laser to cut a 2.552 inch diameter circle, the kerf of the cut would take off an additional 0.005 inches from that as shown in Figure 11. So it would actually be 2.547 inches, which is too loose.

To account for the beam width, I have to increase the diameter by 0.005 inches. So I'd take 2.552 inches, add 0.005 inches, and come up with a final dimension of 2.557 inches. The finished part will come out to a near perfect 2.552 inches in diameter.

Designing Paper Transition Sections

Paper transitions are another part that often have fit problems. Typically what happens is that you end up with a fit that is too tight on the small tube, that splits open when you slide it over the tube as shown in Figure 12. You can also see problems where the other end of the transition does the same thing when you try to mate it with the bigger diameter tube.

The reason has to do with the thickness of the paper from which the transition is made from.

When you roll up a cone created using a flat template,

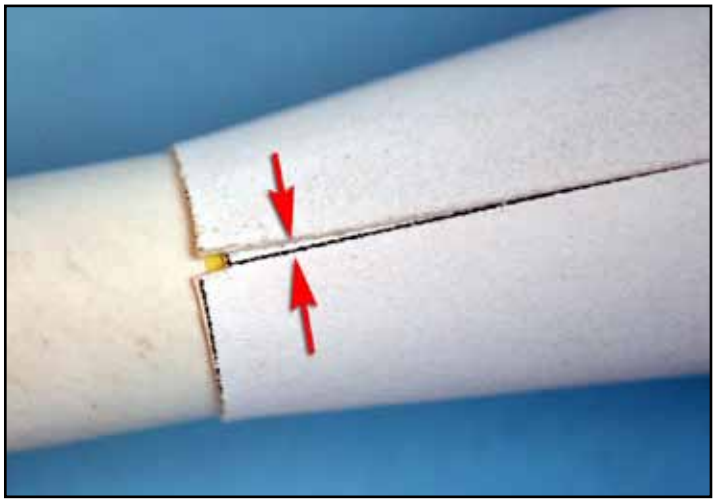

Figure 12: A tight transition will cause the edges to pull apart when it is slid on the tube.

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the assumption is that the inside surface should slide over the tube. But actually, the templates were created so that the outside surface matches the diameter of the tube. Therefore, there is an interference fit when you try to slide it over a tube. Whenever there is an interference fit, something has to give. The best case scenario is for the paper fibers to stretch. But what is more likely is the seam joining the edges together will split open like shown in Figure 12.

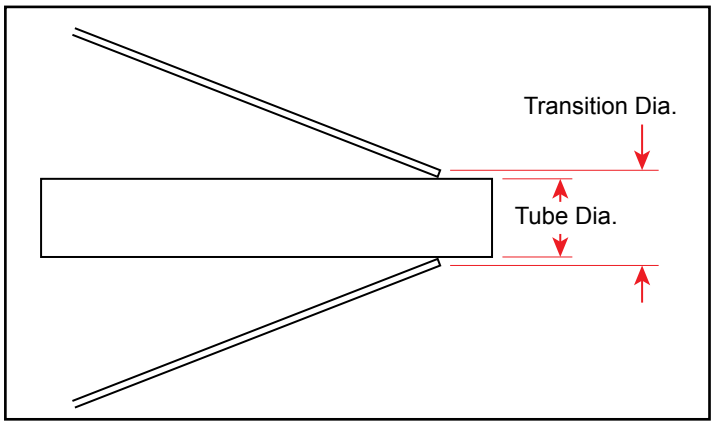

Figure 13: The thickness of the paper used to make a transition affects the diameter. When designing a transition, you need to use the outer diameter of the paper when calculating the dimensions.

To solve this fit problem, you need to design the part slightly larger. The small diameter should not be equal to the outer diameter of the tube it slides over, but be larger by twice the thickness of the paper as shown in Figure 13.

So for example: the transition must fit over a BT-20 tube (O.D. = .736 inches), and the paper of the transition is index-card paper, has a thickness of 0.009 inches. When you go to design the transition, such as in RockSim or from the equations in the book *Model Rocket Design and Construction* (www.ApogeeRockets.com/Rocket_Books_Videos/Books/Model_Rocket_Design_And_Construction), you need to set the diameter of that end of the transition to be 0.018 + 0.736 = 0.754 inches.

Now for the big end of the transition, which was discussed in the last issue of this newsletter (www.ApogeeRockets.com/Education/Downloads/Newsletter354.pdf), I mentioned that the diameter should be set to exactly the diameter of the tube. I still stick with that design rule. The reason, as discussed in the article, is that you don't want any overhang over the tube. That would require extra work to sand it down. It is best to use a shelf hanging out of the tube for the transition to mate to.

The final fit issue with transitions is the glue tab that overlaps where the edges mate. Since the overlap piece

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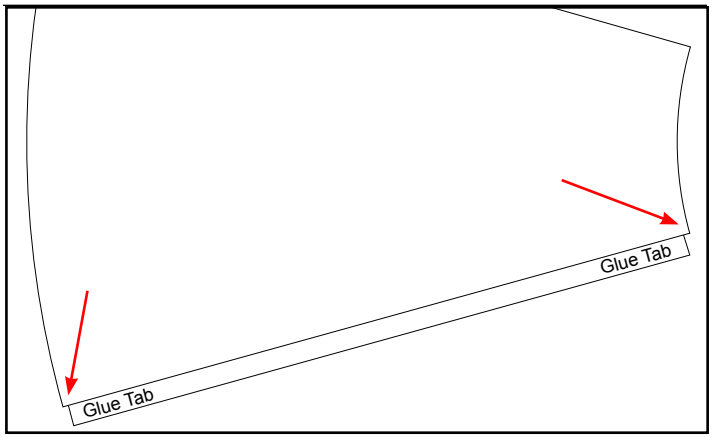

Figure 14: Shorten the length of the glue tab, so that the tab doesn't touch the tube when it is assembled.

is the thickness of the paper, it adds to the interference problem when you slide the transition over the tube. Fortunately, this is easy to solve. I don't allow the overlap to extend to either end of the transition. I cut a notch out of the overlap on the ends, so that the overlap portion starts 1/16 inch (1.5mm) from each end as shown in Figure 14. That means that the shroud is unsupported at both ends. But I allow for the glue to seal the gap shut.

Summary

If you like the ability to control the fit of parts in your rockets, then I'd have to say that designing your own rockets is the way to go. But there are a lot of issues that you have to be aware of, and you really have to pay attention to the exact dimensions of the parts your working with. But there is a lot of satisfaction in having parts that fit together nicely. It saves times and is much more enjoyable when assembling the rocket.

And if you don't get a good fit, using the techniques discussed in this article should allow you to fix the fit problems you encounter. Both design and construction go hand in hand, and as you progress in rocketry, you'll see how you need to be able to do both with competence.

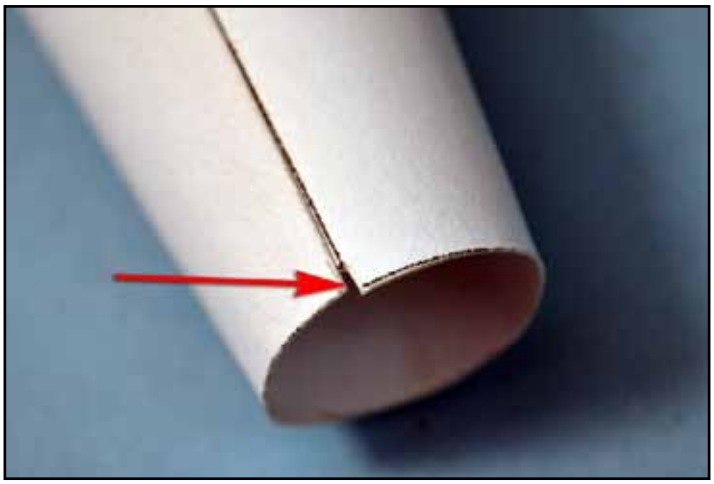

Figure 15: The small gap will be filled by glue when the transition is slid over the body tube.

About The Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. Before he started writing articles and books about rocketry, he worked on the Delta II rocket that launched satellites into orbit. He has a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University in Daytona Beach, Florida, and has worked toward a M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida. Currently, he is the owner of Apogee Components (http://www.apogeerockets.com) and the curator of the rocketry education web site: http://www.apogeerockets.com/education/. He is also the author of the books: *"Model Rocket Design and Construction," "69 Simple Science Fair Projects with Model Rockets: Aeronautics"* and publisher of a FREE e-zine newsletter about model rockets.